REMARKS/ARGUMENTS

In the Office action dated August 16, 2004, the Examiner finally rejected claims 1-22, all of the claims in the Application. Claims 1, 2, 6-8, 16-18 and 22 stand rejected under 35 U.S. C. § 102(b) as being anticipated by U.S. Patent No. 5,585,148 to Suzuki *et al.* Claims 3-5, 9-15 and 19-21 were rejected under 35 U.S.C. § 103(a) as being unpatentable over '148.

In the Specification, no changes

In the Claims, claims 1, 5, 9, 10, 16 and 19 are amended. Claims 6, 12 and 22 are cancelled.

The Invention

The invention is a method of forming a high quality silicon nitride layer at low temperature in an integrated circuit. The method of the invention employs the use of nitrogen radicals to convert silicon to a silicon nitride. The method of the invention may also form a thin nitride layer on an already-grown silicon oxide layer by displacing the oxygen at the top surface and converting at least a portion of silicon oxide to silicon nitride. The method of the invention does not use a plasma discharge, which may cause substantial damage to the silicon wafer. The method of the invention generates large quantities of nitrogen radicals on or near the surface of a silicon layer, or silicon oxide layer, which is to be converted to silicon nitride. The radicals are generated by the photolysis, or photo-dissociation, of NH_3. The light source used is a Xe_2 excimer lamp which emits at a wavelength of 172 nm, or 7.21eV in energy. The direct illumination of the wafer surface at such an energy level may generate photoelectrons and a charged surface that may participate in the nitridation process. The work function of silicon is

less than 5eV, so electrons can have over 2.2eV of kinetic energy. Electron attachment of the low energy electrons may generate negatively charged species, such as NH_2^-, that are quite stable. Adsorbed molecules on the surface of the substrate may also play a role in the nitride layer growth. The growth of the film may be assisted by a field across the growing dielectric layer where a positively charged interface attracts negative ions.

The Applied Art

U.S. Patent No. 5,585,148 to Suzuki *et al.* describes a process for depositing a variety of layers of material on a silicon wafer. Among the material deposited is SiN, however, such deposition does not use photo-dissociation of a nitrogen-containing gas, as described in the Application: a layer of SiN, as described in the applied portion of the reference, is CVD'd by a chemical reaction of NH_3 and SiH_4, which are passed over a wafer, and which results in deposition of a SiN layer. Although the reference describes the use of a light source, such light source is described as a multi-line UV or visible light source, which will operate, at a minimum of a wavelength greater than 200 nm. Col. 6, lines 27-30, col. 9, lines 47-50, and col. 12/lines 20-24, which wavelength and energy are clearly insufficient to photo-dissociate NH_3 into N or N_2, as would easily be recognized by one of ordinary skill in the art. The source of energy for the CVD of various material in the '148 reference is a plasma which is generated in a plasma chamber portion of the apparatus described in the reference, and which is applicable to all embodiments of the invention described and claimed in '148.

In '148, the discharge using NH3 generates both light, excited molecules, and radicals. The light is a broad spectrum, with contributions from atomic species N and H, as well

as molecular species NH, NH_2, and NH_3. The wavelength range includes the infrared, visible, and ultraviolet regions. In addition to the light from the NH_3 discharge, the perforated plate allows the excited species to enter the deposition chamber, where it reacts with a silicon-containing gas to lay down the silicon nitride layer. The mechanisms involved are numerous. One of ordinary skill in the art will recognize that this is a difficult-to-control reaction because of all the factors involved. The method of the invention of the '148 patent is appropriate for formation of thick films, which is the stated intent of '148

Comparison of Applied Reference to Applicant's Invention

In Applicant's method of the invention, no plasma is struck involving NH_3. Simply, NH_3 reacts with silicon from the substrate, aided by the 172 nm wavelength light generated by the xenon excimer. No other wavelengths are used. The xenon excimer light generates a photoelectron from the surface of the silicon substrate, which interacts with a NH_3 molecule, which adsorbs to the silicon surface and reacts to form a thin silicon nitride layer. This is a film no thicker than 5 nm, which is an excellent diffusion barrier to prevent subsequent silicon oxidation at high temperatures.

The Examiner applied '148, col. 9, lines 47-50 and col. 12, lines 20-24 as anticipating use of a xenon excimer lamp having a wavelength of 172 nm. This is not correct. Output from a Xe discharge and Xe excimer are quite different. The excimer lamp is known for its "spectral purity," *i.e.*, no other wavelengths are emitted. A discharge light source, as required by the disclosure of '148, is extremely broad and may have many peaks, as in the Xe lamp spectrum shown below. In addition, a typical transmitting plate, as in quartz used in the '148

apparatus and method, has poor light transmission below 190nm. The intent of the '148 patent is to not use light below 190 nm. The method of the invention requires the light wavelength to be below 200 nm; the xenon excimer light required by the method of the invention is tailored to transmit only at 172 nm.

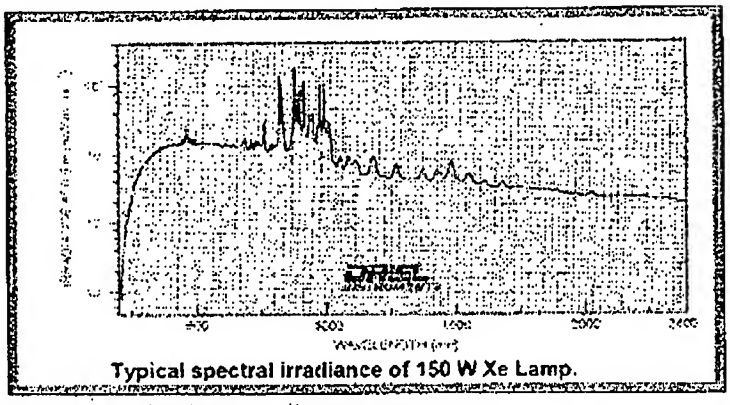

Figure 1. Xe discharge lamp spectrum.

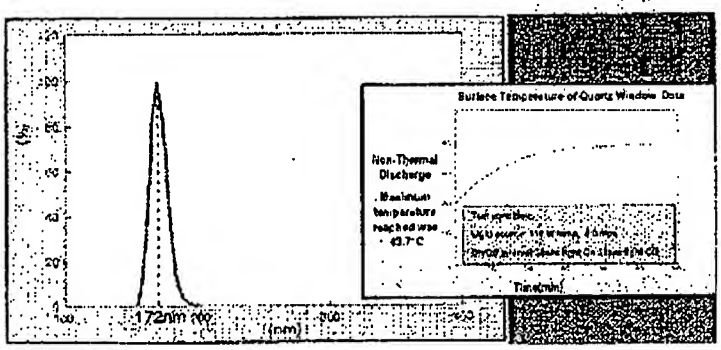

Figure 2. Xe excimer lamp spectrum.

The following table identifies major differences between the '148 reference and Applicant's method of the invention:

	U.S. Patent No. 5,585,148	Application
Film material	SiO_2, SiN	SiN
Silicon source	SiH_4, Si_2H_6, $SiCl_2H_2$, alkoxysilane, siloxane, or silanol.	Si from the substrate
Reactant gas	Plasma excited O_2, O_3, N_2O, H_2O, N_2, NH_3, N_2H_4, H_2, Ar, *etc.*	N_2 or NH_x where x = 1, 2, or 3.
Light used	Broad or multi-line UV and visible from plasma discharge of O_2, O_3, N_2O, H_2O, N_2, NH_3, N_2H_4, H_2, Ar, *etc.* Wavelength >200 nm due to cutoff of perforated transmitting plate	Solely 172nm from Xe excimer. (no other wavelengths are generated from this lamp).
Reactions	Excited gases from the plasma take part in deposition of the film, thus the need for a perforated plate.	Reaction is with nitridation species, substrate surface and radiation.
Temperature	Up to several hundred°C	Up to 400°C
Pressure	1 to 20 Torr	<0.2 Torr
Objective	Films 250nm to 500nm thick for optics, interlayer, *etc.*	Film < 5nm thick for diffusion barrier

The Claims

Claim 1 has been amended to specifically recite the characteristics of the light used in the method of the invention, to specifically recite the gases which may be used, and to specifically recite that the silicon nitride layer formed by the method of the invention is less than 5 nm in thickness and is formed from the silicon wafer and the dissociated nitrogen. The

Examiner has applied '148, col. 9, lines 47-50, which is a portion of the third example of the reference. There is no mention of "dissociation," nor of an excimer lamp in this portion of the reference. Elsewhere in '148, the Patentee describes the third example as having using a plasma source, and using a light for *irradiating the surface of the wafer*. Col. 4, lines 6-24. This is a very different process than that describes and claimed by Applicant. Claim 1 is not anticipated by any portion of '148 because '148 does not teach nor suggest that a nitrogen-containing gas is dissociated by an excimer lamp; '148 teaches that a chemical reaction between a nitrogen-containing gas an a silicon containing gas is used to form SiN, which is deposited by CVD on a silicon wafer. The use of a plasma is required by the teaching of '148; Applicant's method of invention does not require, need, or contemplate use of plasma. To eliminate the plasma from the method of the '148 patent would render the method of '148 inoperable.

Applicant claims a temperature range of between about room temperature and 400°C. The Examiner applies '148, col. 9, lines 37-39, which recites heating the substrate to a temperature of between room temperature and several hundred degrees, however, as the elements of the claim may not be separated for examination, the Examiner must find a reference wherein photo-dissociation *and* low temperature SiN formation are present, and the Examiner has failed to provide such a reference. Applicant has provided prior art materials regarding photo-dissociation, which teach use of high temperatures, and Applicant has described a technique for photo-dissociation at a low temperature. The Examiner has not provided a reference which teaches or suggest photo-dissociation of a nitrogen-containing gas and formation of a SiN layer on a silicon wafer at low temperature. Claim 1 is allowable over the applied art.

Claim 2 recites that the pressure in the chamber is between 5 mTorr and 200 mTorr. The Examiner has applied a reference wherein the pressure is between 1 Torr and 20 Torr. Col. 9, lines 44-46. As explained in Applicant's Specification, the method of the invention includes forming a silicon nitride layer at low temperature and low pressure, which is different from the prior art, and which is certainly not anticipated by '148. Claim 2 is allowable over the applied art.

Claims 3-5 and 8 are allowable with their allowable parent claim.

Claim 7 recites that "...said forming includes providing a positively charged interface across the nitride layer." The Examiner has applied '148, col. 9, lines 52-57 in rejecting this claim under 35 U.S. C. § 102(b). The applied portion of '148 reads:

> *As a result, NH_3 gas was allowed to flow through the through-holes 16 and SiH_4 gas flowed through the ejection holes uniformly toward the substrate 2. The film formation was conducted to obtain a desired film thickness. Consequently a SiN film was formed uniformly with high quality on the substrate 2.*

Neither Applicant nor the undersigned can find any teaching or suggestion that the applied portion of the reference regarding "providing a positively charged interface across the nitride layer." Although the Examiner continues the same argument as made in the first Office action, the Examiner has not explained how the cited portion of '148 anticipates the language of claim 7. Claim 7 is allowable over the applied art.

Claim 9 is allowable for the reasons set forth in connection with claim 1: there is no teaching nor suggestion in '148 that an excimer lamp be used to dissociate a nitrogen-containing gas into nitrogen which is used to form a layer of SiN on a silicon wafer at a temperature of between about room temperature and 400°C. The '148 patent is applied as a 35

U.S. C. § 102 reference, and requires a plasma in order to function; Applicant's invention does not require a plasma. Claim 9 is allowable over the prior art of record.

Claims 10, 11, 13 and 15 are allowable with their allowable parent claim.

Claim 14 is allowable for the reasons set forth in connection with claim 7.

Claim 16 currently amended and is allowable for the reasons set forth in connection with claims 1, 7 and 9.

Claims 17-21 are allowable with their allowable parent claim.

In light of the foregoing amendment and remarks, the Examiner is respectfully requested to reconsider the rejections and objections state in the Office action, and pass the application to allowance. If the Examiner has any questions regarding the amendment or remarks, the Examiner is invited to contact the undersigned.

Provisional Request for Extension of time in Which to Respond

Should this response be deemed to be untimely, Applicants hereby request an

extension of time under 37 C.F.R. § 1.136. The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any over-payment to Account No. 19-1457.

Respectfully submitted,

Date: 11/15/04

David C. Ripma
Registration No. 27,672

David C. Ripma
Patent Counsel
Sharp Laboratories of America, Inc.
5750 N.W. Pacific Rim Highway
Camas, WA 98607

Telephone: (360) 834-8754
Facsimile: (360) 817-8505